Content

F 1 Control systems/interlocks

The subsequently described trips, interlocks and control sequences must be realised in the PLC system.

The control system will be provided by the customer.

The descriptions included in this chapter are only designed for a better understanding of the control systems/interlocks. The documents on instrumentation and control systems are the sole binding documentation for the structure of the control system.

F 1.1 Trips

A number of trips have been provided for safe compressor operation. All trips and their limit values are included in the alarm list.

Trips act on the high-voltage switch of the motor.

During compressor-start-up, some trips will have to be inactivated and/or modified:

Trip	Duration of the trip/modification
Shaft vibration	The value is inactivated, until nominal speed is reached
Suction temperature	The value is inactivated (the duration of the trip may be determined during commissioning, see logic diagram).

F 1.2 Compressor readiness for start-up

The following conditions must be met to be able to start the compressor (high-voltage switch ON):

Component /process parameter	Status
Auxiliaries	activated
Auxiliary oil pump	ON
Oil pressure	> trip value
Oil temperature	> 15°C
Seal gas pressure process gas	> depending on stage pressure
Inlet guide vanes (IGV)	MIN. position
Trips	none
Re-start interlock	elapsed A re-start interlock of approx. 10 minutes is activated subsequent to any compressor stop.

F 1.3 Auxiliary oil pump (AOP)

Plant status	Tasks of control system/interlocks
Plant out of operation	Maintain readiness for start-up: When the oil inlet temperature drops to +5°C the auxiliary oil pump (and thus the oil demister) and the oil heating are switched on. When the oil inlet temperatures reaches +15°C, the auxiliary oil pump (and thus the oil demister) are switched off. The oil heating remains ON (on stand-by).
Compressor START	Prior to start-up, the compressor must be heated by circulating warm oil. Pre-heating time: approx. 10 min. After nominal speed has been reached, the auxiliary oil pump continues operating for approx. 60 seconds. During this time, it cannot be stopped manually. After this time has elapsed, it is shut down automatically. Any parallel operation of main and auxiliary oil pump over longer periods of time should be avoided altogether.
Compressor operating	When the oil pressure drops below the set limit value during operation, the auxiliary oil pump is switched on. Once this happened, it can only be switched off manually.
Compressor STOP	The auxiliary oil pump is switched on and continues operating for 60 minutes. After this time has elapsed, the auxiliary oil pump is shut down automatically.

F 1.4 Oil heating

Plant status	Tasks of control system/interlocks
Plant out of operation	Maintain readiness for start-up: When the oil inlet temperature drops to +5°C the auxiliary oil pump (and thus the oil demister) and the oil heating are switched on and are operating for an adjustable period of time.
Compressor START	Oil heating ON (on stand-by).
Compressor operating	Oil heating ON (on stand-by).
Compressor STOP	Oil heating ON (on stand-by).

F 1.5 Oil demister

Plant status	Tasks of control system/interlocks
Plant out of operation	At the moment the auxiliary oil pump is switched on, also the oil demister must be activated.
Compressor operating	The oil demister must continue operating in the entire course of compressor operation.
Compressor STOP	After the order to stop the compressor has been given, the oil demister must continue operating, until the relubricating time of the auxiliary oil pump

F 1.6 Cooling water system

Plant status	Tasks of control system/interlocks
Plant out of operation	
Compressor START	
Compressor operating	
Compressor STOP	

F 2 Controllers

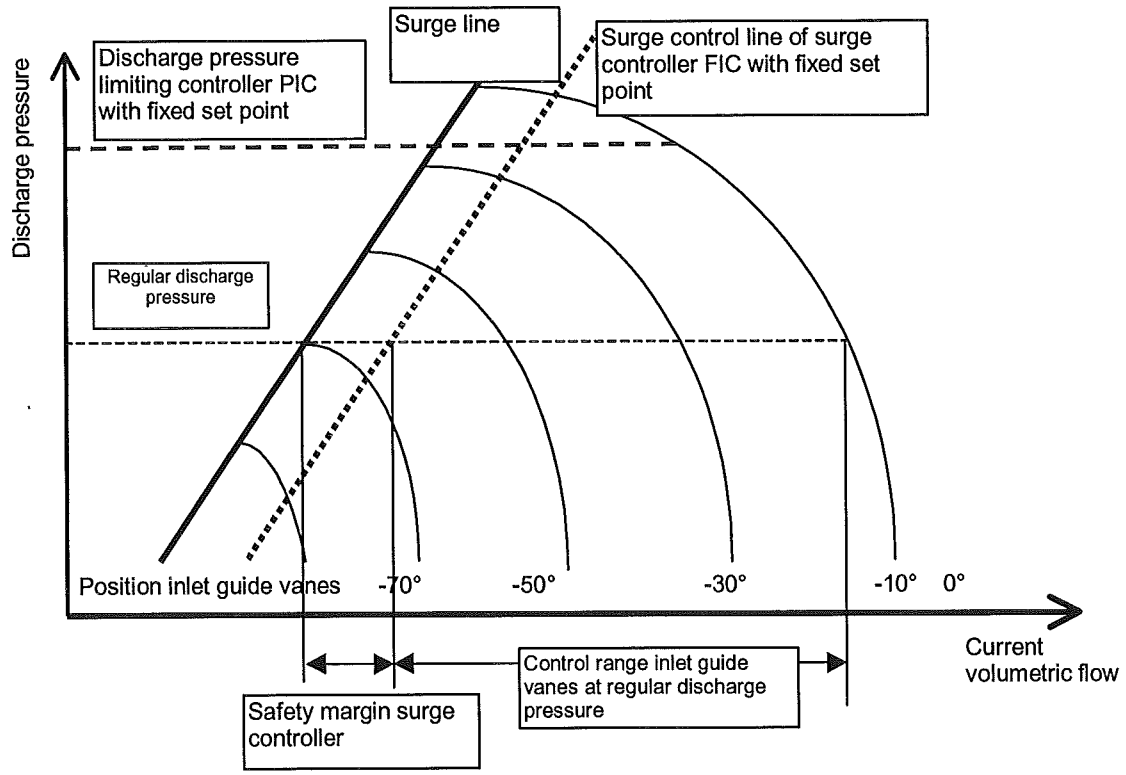
F 2.1 General information

Turbo compressors require a minimum volumetric flow to operate in a stable range.

Whenever the volumetric flow falls below this minimum volumetric flow, the flow in the impeller stalls. This phenomenon which is referred to as „surging" represents an excess stress to the mechanical components and should therefore be avoided. To be able to operate the compressor in the stable range even at reduced flow, the compressor has been equipped with a bypass/blow-off valve which is designed to compensate for the difference between current and minimum volumetric flow. The bypass/blow-off valve is controlled by means of the surge controller.

The dividing line between stable and unstable operation is referred to as surge line. Its course depends on various factors (temperature, pressure, etc.).

A safety margin must be defined between surge line and surge control line to ascertain stable controlling characteristics.



The control system should include the following controllers:

Safety controllers:	Surge controller FIC Discharge pressure limit controller PIC Motor current limit controller UIC
Process controllers:	Inlet guide vane control
Others:	HIC Bypass / Blow Off valve

F 2.2 Surge controller FIC

As the surge controller is a safety controller, it is activated only at extreme operating conditions. Its task is to keep the compressor from surging.

The actual value **PV** of the surge controller is a dimensionless variable calculated from the following measured values:

$dp_{suction\ nozzler}$	**Differential pressure across suction nozzle**
dp_{stage}	**Differential pressure across stage**

The calculation is based on the following equation:

$$PV = \frac{dp_{suction\ nozzle}[mbar]}{dp_{stage}[mbar]} \times 1000$$

The set point **SP** of the surge controller is a fixed value ("fixed bypass/blow-off line" = surge line plus safety margin) and is set by ATLAS COPCO staff during commissioning.

The surge controller compares **SP** and **PV**, the difference being the error **XD=SP-PV**. The controller always tries to obtain an error of "0".

A negative error (**SP<PV**) leads to a decreasing controller output signal (bypass /blow-off valve closes), a positive error (**SP>PV**) leads to an increasing controller output signal (bypass/blow-off valve opens).

The current surge controller output is conducted to the MAX selector (with the higher value being further processed to the bypass/blow-off valve).

Safety position of the bypass/blow-off valve is open (4 mA correspond to valve position 100 percent open, 20mA correspond to valve position 0 percent open.). The output of the MAX selector is conducted to the bypass/blow-off valve via a reverse function.

With the compressor standing still, the process value PV of the surge controller is set to 0 and the error is at its maximum (XD=SP-0).

The broken wire monitoring signal of $dp_{suction\ nozzle}$ is delayed by 30 seconds.

In case of measurement failure dp_{stage} the substitute value must be set to 100%.

F 2.3 Discharge pressure limiting controller PIC

As the discharge pressure limiting controller is a safety controller, it is activated only at extreme operating conditions. Its tasks is to keep the compressor discharge pressure from increasing above a maximum permissible value.

The process value PV of the controller is formed by the compressor discharge pressure. The controller set point SP is formed by a fixed value which is set by Atlas Copco staff during commissioning.

The discharge pressure limiting controller compares PV and SP, the difference between these values being the error XD=SP-PV.

A negative error (SP<PV) leads to an increasing controller output signal (bypass/blow-off valve opens), a positive error (SP>PV) leads to a decreasing controller output (bypass/blow-off valve closes).

The current controller output of the discharge pressure limiting controller is conducted to the MAX selector, just like that of the surge controller.

F 2.4 Motor current limit controller UIC

As the motor current limit controller is a safety controller, it is activated only at extreme operating conditions. Its task is to avoid any overload of the compressor main driving motor.

The process value PV of the power controller is formed by the power or current input of the main driving motor. The set point SP of the power controller is a fixed value and is set by Atlas Copco staff during commissioning. The power controller compares PV and SP, the difference between these two values being the error XD=SP-PV.

A negative error (SP<PV) leads to a decreasing controller output signal (inlet guide vanes are closed), a positive error (SP>PV) leads to an increasing controller output signal (inlet guide vanes are opened).

The current controller output of the motor current limit controller is conducted to a MIN selector. The output of the low selector is further processed to the IGV position controller

F 2.5 Inlet guide vane control

Adjusting the position of the inlet guide vanes is a means to control the volumetric flow towards the process or the suction and/or discharge pressure in accordance with current demand.

Opening of the inlet guide vanes leads to an increase in volumetric flow toward the process and in discharge pressure and to a reduction in suction pressure. Closing of the inlet guide vanes leads to a reduction in volumetric flow towards the process and to an increase in suction pressure.

The compressor operating point should be selected in a way that the bypass/blow-off valve remains closed as long as the inlet guide vanes are not adjusted to their MIN operating position.

Closing of the inlet guide vanes is possible any time. Opening, however, may be limited by power controller UIC.

Inlet guide vane safety position is closed (0 percent = 4 mA = MIN position, 100 percent = 20 mA = MAX position).

The output of the IGV controller is connected to the output low clamp OUTL of the motor current limit controller UIC. The output of UIC is connected to a MIN selection. The lower value between output of Ramp 1 and output of UIC is transferred to the inlet guide vanes.

F 2.6 Hand indicating controller HIC for bypass/blow-off valve

The HIC is designed to open or close the bypass/blow-off valve.

Opening of the bypass/blow-off valve is possible any time. Closing, however, may be limited by the discharge pressure limiting controller or the surge controller.

F 2.7 Ramps

When the compressor is running (run-up time has elapsed) and the load signal is changed from unload to load, **ramp 1** is started to run from 0 percent to 100 percent. **Ramp 1** initiates a controlled opening process of the inlet guide vanes to enable smooth take-over of control by the inlet guide vane process controller. The inlet guide vanes are operated from their MIN position to the MIN operating position.

When the load signal is changed from load to unload and the bypass/blow-off valve is more than 95% open, **ramp 1** ramps from the current value towards 0 percent. The inlet guide vanes are adjusted to their MIN position.

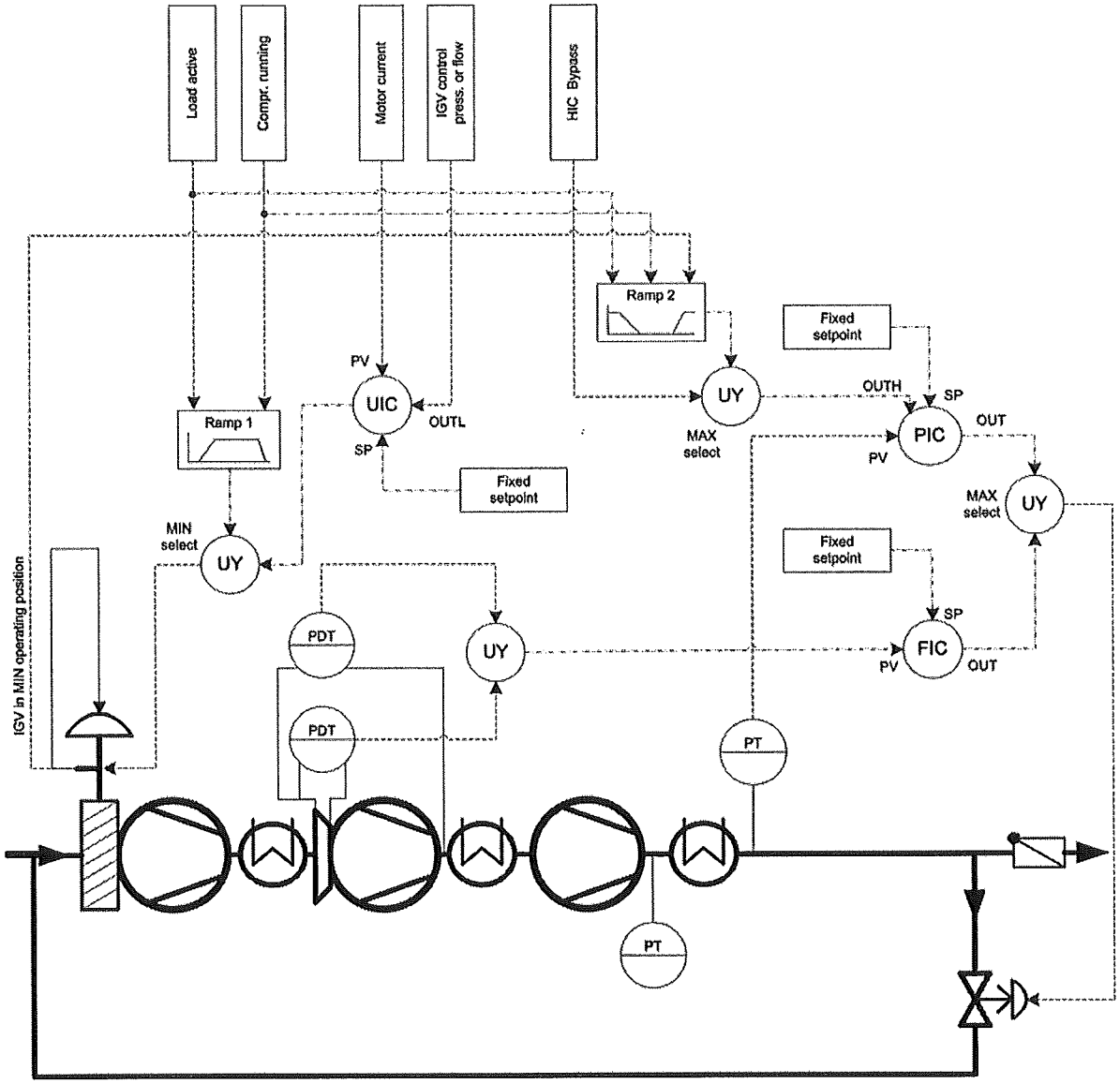
Ramp 1 also ramps from the current value towards 0 percent when the compressor is stopped.

The inlet guide vane MIN operating position and ramp-up/ramp-down velocities are set by Atlas Copco staff during commissioning.

When the load signal is adjusted to load, and the inlet guide vanes have reached their MIN operating position, **ramp 2** is started to run from 100 percent to 0 percent.

When the load signal is changed from unload to load or the compressor is shut down, ramp 2 is started to run from the current value to 100 percent and the bypass/blow-off valve is opened. When the bypass/blow-off valve is approx. 95 percent open, ramp 1 is started to run from 100 percent to 0 percent and the inlet guide vane is adjusted to its MIN position.

Ramp-up/ramp-down velocities are adjusted during commissioning by Atlas Copco staff.



PIC	=	pressure controller
UIC	=	power controller
FIC	=	surge controller
HIC	=	manual/hand indicating controller
UY	=	calculation / logic function
PT	=	pressure transmitter
PDT	=	pressure differential transmitter